University of Chester

Department of Clinical Sciences and Nutrition

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Nutrition and Golf performance

By Michael Robinson

J40580

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A review of Nutrition in Golf performance

Abstract

Nutrition in Golf is a relatively new area of research with only a small amount of published studies. Golf nutrition is distinct from other sports primarily due to the variable conditions faced by players over an extended period of time. Despite that only a low to moderate exercise intensity is maintained, players are required to make multiple maximal velocity swings requiring high level motor skill whilst cognitive functioning is challenged through decision making on every shot, often under intense pressure. Caffeine supplementation has been the most investigated topic with findings of improved performance in certain areas of the game such as driving and putting whilst fatigue appeared to be attenuated towards the end of a round. Dehydration has been shown to be prevalent even in the elite amateur game with a significant decline in a range of performance variables found with only mild-dehydration. Carbohydrate consumption has been shown to prevent the decline in blood glucose experienced over a round, however an optimal consumption protocol has not been established. Future research should further investigate nutritional techniques to offset the physical and mental challenges arising over a round of golf.

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Abbreviations

BM – Body Mass
GI – Glycemic Index
HGI – High Glycemic Index
LGI – Low Glycemic Index
HR_{max} – Maximal Heart Rate
UO – Urine Osmolality
USG – Urine Specific Gravity

1. Introduction

To date, most of the scientific research surrounding golf performance has focussed on the psychology and biomechanics of the game with only a limited amount conducted on the topics of exercise and nutrition (Farrally et al., 2003). Of the seven published studies with a nutritional focus, four investigated the effects of caffeine (or another stimulant) supplementation, two investigated the effects of dehydration (Smith, Newell, & Baker, 2012; Magee, Gallagher, & McCormack, 2016) whilst only one study has investigated the effects of carbohydrate consumption (in combination with caffeine) during play (Stevenson, Allison, & Hayes, 2009). The lack of research in this area may be because of the perception that Golf is a low intensity sport (Hayes, van Paridon, French, Thomas, & Gordon, 2009) inferring that performance is not likely to be limited by dietary choices. Furthermore it is not uncommon to see successful professional players who would be classified as overweight reinforcing this perception. However, it is becoming more apparent in the professional and elite amateur game that players seek advice from sports science professionals on nutritional strategies to optimise performance as new research and trends emerge (Smith, 2010).

During a round of Golf, players walk courses which vary in length (from 5500 to over 7000 yards) and topography whilst playing in a variety of weather conditions (Smith, 2010). Depending on these variables, along with the competition format and general pace of play, a round of Golf may last from four hours in amateur competitions to over five hours in professional tournaments (Hayes et al., 2009). Hayes et al. (2009) found that the average distance players covered over 18 holes on a relatively flat, 6244 yard course was 8.3 ± 0.5 km when using a golf trolley to transport their clubs. This form of exercise performed over an extended period of time will challenge the body's ability to maintain euglycemia and euhydration particulary on longer, more undulating courses in hot and humid conditions (Stevenson et al., 2009). Dehydration and hypoglycaemia have been shown to impair cognitive functioning (Maughan, Shirreffs, & Watson, 2007) and motor performance (Smith et al., 2012), of which both are strongly assoicated with Golf performance (Smith, 2010). Given these physiological challenges, optimal nutrional stratgies to prevent a decline in performance may be an important area for future research.

This review will focus on the nutritional demands during play and how these demands may impact performance. Existing research will be reviewed including how the consumption of carbohydrates, fluids or other nutritional supplements during play may attenuate a decline in performance.

2. Nutritional Requirements during Play

2.1 Substrate Utilization

During 18 holes of Golf it has been shown that players reach a range of exercise intensities dependent upon individual cardiorespiratory fitness level and the golf course characteristics. Broman, Johnsson and Kaijser (2004) measured the heart rate of 19 male golfers in 6 young (21 - 32 years), 7 middle-aged (40 - 58 years) and 6 elderly (69 - 80 years) players over 18 holes. The course was 6090 yards long and mainly flat with only a few steep uphill/downhill sections. A maximal exercise test was conducted to determine aerobic capacity ($\dot{V}O_2max$) and maximal heart rate (HR_{max}). It was determined that the young and middle aged spent the majority (191 ± 27 minutes) of their round between 50 and less than 70 %HR_{max} indicating a light to moderate exercise intensity (ACSM, 2011). Young players only spent a few minutes at a high intensity (> 70 %HR_{max}) activity level whereas elderly players spent over 70% of total time (161 ± 89 minutes) at this intensity. Collectively this was similar to Hayes et al. (2009) who found an average intensity of 56 ± 4 % HR_{max} in 8 middle aged players (50 ± 19 years) on a relatively flat, 6244 yard course in similar temperatures 16 ˚C to 20 ˚C. However Stauch, Liu, Giesler and Lehmann (1999) found middle aged (53 ± 11 years) players reached a high exercise intensity for 20% of their round (44 minutes) on a very hilly course in warmer conditions (22 ± 7 ˚C). In addition to the walking element of golf, certain types of golf shot such as the drive, require a powerful, dynamic movement fuelled primarily through anaerobic pathways. However given the proportionately small amount of time it takes to complete one swing; less than 1.3 seconds (Smith,

2010) with approximately 12 to 14 drives per round, it may be assumed that the swing itself contributes only a small amount to the overall exercise intensity and that the nutritional requirements for this anaerobic part of the game are negligible in comparison to the rest.

Given that carbohydrate utilization increases with exercise intensity (Maughan & Gleeson, 2010) and that there are limited stores of carbohydrate within the body (approximately 2500 kcal), elderly players in particular may be at risk of depleting glycogen stores leading to fatigue if carbohydrates are not consumed during play (Jeukendrup, 2014). However it has been shown that fat oxidization contributes increasingly to high intensity exercise lasting longer than two hours (Romijn et al., 1993) which may attenuate glycogen depletion in this population. Furthermore even at a moderate exercise intensity, approximately 50% of total energy is derived from carbohydrates (Romijn et al., 1993) indicating the need for players to consume carbohydrates to maintain blood glucose levels and slow glycogen depletion over this prolonged duration (ACSM, 2016).

2.2 Fluid Intake

A round of Golf will lead to significant fluid losses if not replaced (Smith, 2010). Fluid losses will be more severe when playing in hot and humid conditions (ACSM, 2007). Dehydration can be defined as a Urine Specific Gravity (USG) score > 1.020, a Urine Osmolality (UO) sample > 900 $mOsm \cdot kg^{-1}$ or a loss in body mass (BM) > 2 % (ACSM, 2007). The key areas which dehydration may impact Golf performance are; motor skill which is required to execute each swing (Smith, 2010), cognitive functioning (Maughan et al., 2007) which aids decision making and on course tasks such as distance perception (Smith et al., 2012) and endurance capacity which may lead to premature fatigue particularly in those with a lower exercise capacity (Armstrong, Costill, & Fink, 1985).

Dehydration has been shown to be prevalent in American college golf. Magee et al. (2016) found that 40% of 15 elite college golfers commenced an 18 hole tournament dehydrated (USG > 1.020, (ACSM, 2007)) which increased to 60% dehydrated post-round with a significantly higher USG (1.023, $p > .05$). Those who were dehydrated had a significantly higher score than those euhydrated (79.5 ± 2.1 vs. 75.7±3.9, $p < .05$). This is despite players being unrestricted to consume fluids in comparison to other sports where play is continuous. Furthermore Smith et al. (2012) investigated the effects of mild dehydration on a range of performance variables including 7 low handicap players (age, 21 ± 1.1 years; handicap, 3.0 ± 1.2) in a randomised counterbalanced design. Mild dehydration impaired motor skill expressed by shot distance (114.6 ± 12.9 vs 128.6 ± 8.8 m, $p = .04$) and off-target accuracy (7.9 ± 2.0 vs 4.1 ± 0.8 m ; $p = .001$) whilst cognitive functioning expressed by the error in distance perception was also impaired (8.8 ± 4.7 vs. 4.1 ± 3.0 m, $p < .001$) compared to the euhydrated trial. However there was a large variation in the loss of BM (- 1.5 ± 0.5 %BM) in the dehydration trial which does not provide a decisive threshold at which these effects occur.

Given that sweat rates and sweat composition varies considerably, it is not possible to provide one fluid replacement strategy for all (Magee et al., 2016). However the ACSM recommend minimising BM losses to < 2% by the frequent consumption of fluids including sodium. However given the findings of Smith et al. (2012) a 1 % limit may lower the risk of dehydration on golf specific performance.

2.3 Blood Glucose

The importance of maintaining euglycemia to prevent a decline in performance has been well documented in a range of endurance sports (Jeukendrup, 2014). Symptoms of acute hypoglycaemia may include depressed central nervous system activity which is associated with a lower capacity to concentrate (Benardot, 2012) as well as an increase in ratings of self-perceived fatigue and lower work rates (ACSM, 2016; Broman et al., 2004).

Hayes et al. (2009) found that blood glucose declined after only 9 holes (5.0 to 4.7 $mmol \cdot l^{-1}$) on a standard length course (6245 yards) in moderate conditions (temperature, 16.4 ± 4.0 ˚C; humidity, 70.3 ± 9.8 %) including eight male recreational participants (age, 50 ± 19 years; weight, 88.6 ± 10.7 kg; handicap, 12.5 ± 2.7). A further decline in blood glucose was prevented following the consumption of carbohydrate snack on the 10th hole, although the participants in this study did not carry their clubs which has been shown to have a significantly ($p < .05$) lower average oxygen consumption (18.3 vs. 22.4 $ml \cdot kg \cdot min^{-1}$) than walking and carrying clubs (Sell, Abt, & Lephart, 2008) which may accelerate the fall in blood glucose. Furthermore, the breakfast that participants consumed before play was not recorded which may have caused considerable variation in blood glucose levels pre-round.

In contrast Broman et al. (2004) found blood glucose remained stable until the 15th hole in all age groups during a non-competitive round on a 6090 yard course which also included a snack (sandwich and banana) after the 9th hole. Over the remaining three holes blood glucose decreased in the elderly players by 33% ($p < .05$) compared with 10% and 20% ($p < .05$) in the middle-aged and young golfers respectively. This confirms that the stability of blood glucose is related to exercise capacity indicating that elderly players may benefit from a more frequent consumption of carbohydrates. However, similar to Hayes et al. (2009) no standard breakfast was provided and performance was not measured. Although no investigations have reported a large enough decrease in blood glucose over 18 holes to be classified as hypoglycaemia (< 4.0 mmol·l^{-1} (Cox, Gonderfrederick, Schroeder, Cryer, & Clarke, 1993)), both investigations presented here infer that it may be possible to reach this level if a snack had not been consumed. The ACSM (2016) do not provide a specific carbohydrate recommendation for low to moderate intensity exercise over an extended duration. However a general recommendation for all exercise exceeding one hour is to consume 30 to 60 g·hour^{-1} of carbohydrate to contribute to muscle fuel needs and maintain euglycemia (ACSM, 2016).

3. Golf Nutrition Research

3.1 Summary of existing research

A range of databases including SPORTdiscus and PubMed were reviewed to identify research with a focus on nutrition and Golf performance. The following key words were used in search engines in combination with 'Golf' to filter results; nutrition, food, drink, diet, dietary, supplement, caffeine, hydration, dehydration, blood glucose and consumption. Relevant research was identified as those with a nutritional focused objective such as an intervention using a sports supplement/macronutrient or an observation of nutritional habits. A total of seven investigations met these criteria, see Table 4.1. Related research such as Hayes et al. (2009) who developed a treadmill simulated round of Golf and Broman et al. (2004) who identified the exercise intensity of a round of Golf were classified as having a physical activity/exercise focus so were excluded. It should be noted that these related studies measured similar variables such as blood glucose and hydration levels which are the primary dependent variables in some of the nutrition focused studies. Therefore other related research may be referred to.

Table 4.1 Golf Nutrition Research from 2007 to 2016

Reference	**Topic**	**Key Findings**
(Bristow, 2016)	Caffeine consumption before and during 18 holes with a focus on driving performance.	No significant difference ($p > .05$) in any 18 hole performance variable between CAF and placebo trial. CAF trial appeared to prevent a decline in some drive performance variables including ball speed and total distance compared to placebo (no significant difference between pre and post-round tests, $p > .05$).
(Magee et al., 2016)	Dehydration prevalence before and after a competitive round.	Players that were dehydrated pre-round took a significantly higher number of strokes to complete the round in comparison with their euhydrated counterparts (79.5 ± 2.1 vs. 75.7 ± 3.9, $p < .049$).
(Mumford et al., 2016)	Caffeine consumption before and during a 36 hole competitive tournament.	Total score (76.9 ± 8.1 vs 79.4 ± 9.1, $p = .039$), greens in regulation (8.6 ± 3.3 vs 6.9 ± 4.6, $P = 0.035$), and drive distance (239.9 ± 33.8 vs 233.2 ± 32.4, $P = 0.047$) were statistically better during the CAF condition compared with those during PLA. CAF reported more energy ($P = .025$) and less fatigue ($P = .05$) over the competitive round of golf
(Ziegenfuss et al., 2015)	Creatine (5000mg), Caffeine (50mg), Calcium fructoborate (3mg) and Vitamin D (1000 IU) Supplementation.	Increase in best drive distance (+5.0% (+13.6 yards, $p = .04$)) and a tendency for average drive to increase (+8.4% (+19.6 yards, $p = .07$)).
(Smith et al., 2012)	Effect of Acute Mild Dehydration (-1 to 2 % loss in BM) on Cognitive-Motor Performance in Golf.	Distance impaired, (114.6 ± 12.9 vs. 128.6 ± 8.8 m, $p = .04$); Accuracy impaired (7.9 ± 2.0 vs 4.1 ± 0.8 m, $p = .001$); Distance perception impaired (distance error) (8.8 ± 4.7 vs. 4.1 ± 3.0 m, $p < .001$) in a dehydrated state compared with the euhydrated state.
(Stevenson et al., 2009)	Carbohydrate-Caffeine Sports Drink consumed before and during play.	Putting performance over 5 m and 2 m and self-rated scores for alertness and relaxation showed a main effect for drink ($p < .05$).
(Jäger et al., 2007)	Phosphatidylserine (200mg) Supplementation.	Increased the number of good ball flights (mean: pre-test 8.3 ± 3.5, post-test 10.1 ± 3.0, $p < .05$).

3.2 Caffeine

Caffeine supplementation (independently or in combination with other supplements) has been the most frequent area of investigation in nutritional based golf research to date. Caffeine is a central nervous system stimulant that has been shown to benefit both physical and cognitive performance during endurance exercise (Hogervorst et al., 2008) and performance in skill-based sports such as tennis performed over long periods (Burke, 2008). It is one of the most common supplements used in endurance sport due to its well supported ergogenic effects (Jeukendrup, 2011). Stevenson et al. (2009) were the first to investigate the effects caffiene (1.6 $mg \cdot kg^{-1}$) on one area of Golf performance (putting) although this was in combination with an istonic sports drink (CAF) including carbohydrate (0.64 $g \cdot kg^{-1}$) and electrolytes. The study included 20 male participants (age, 23 ± 4 years; BM, 76.2 ± 7.4 kg; handicap, 15 ± 4) who were habitual caffeine users (157 ± 47 $mg \cdot day^{-1}$). Participants were required to walk a simulated round of Golf performed on a treadmill (Hayes et al., 2009) whilst putting performance was assessed following the completion of each hole. CAF or a flavour matched placebo were consumed pre-round (5 $ml \cdot kg^{-1}$) and at holes 6 and 12 (2.5 $ml \cdot kg^{-1}$) in double blind, randomised, counter-balanced crossover design. The percentage of successful putts from a 2m (72% vs. 58%) and 5m (42% vs. 28%) distance during the final 6 holes were significantly ($p < .05$) higher during the CAF trial compared to placebo and the average distance each putt missed was significantly ($P < .05$) lower over the last 6 holes in the CAF trial. There was a main effect for CAF in self-rated scores of alertness ($p < .05$) and relaxation ($p < .01$). The authors conclude that it was not possible to distinguish between the effects of carbohydrate or caffeine whilst a simulated round of Golf may have underestimated the true exercise intensity compared to a round played in a competitive environment in varying outdoor conditions (Smith, 2010). Therefore further investigation is required to determine whether a carbohydrate and caffeine drink would prevent a decline in fatigue (as indicated here) in real life conditions.

Ziegenfuss et al. (2015) measured a different aspect of golf performance (drive distance) in response to the consumption of a supplement (SP) containing creatine monohydrate, coffee arabica fruit extract (including 50 mg of naturally occuring caffiene), calcium and vitamin D. A total of 27 males (age, 30 ± 7 years; BM, 86.7 ± 11.9 kg; handicap, 5 to 15) were instructed to consume SP or a placebo twice per day for 15 days then once per day for another 15 days which met the manufacturer guidelines for creatine monohydrate loading. Pre and post-round tests of drive performance revealed a significant (p = .04) increase in best drive distance (+ 5%) and a tendency (p = .07) for average drive distance to increase (+ 8.4%) compared to no difference with placebo (- 0.5% and + 1.3% respectively). However the participants were instructed to fast for 12 hours before pre and post testing, therefore the effects of caffeine within the SP may not have influenced results given that it has a half-life of five hours (Cox et al., 2002). Furthermore the caffeine dosage was less than half that used by Stevenson et al. (2009) based on a 75kg BM.

Mumford et al. (2016) were the first to investigate the effects of caffeine during a competitive 36-hole tournament including 12 amateur players (age, 35 ± 14 years; BM, 81.2 ± 13.1 kg; handicap, 5.5 ± 2.7; daily caffeine intake, 102 ± 60 mg·day^{-1}). Employing a similar research design to Stevenson et al. (2009), participants were randomly assigned either caffeine (CAF, 2 mg·kg^{-1}) or placebo consumed pre-round and following the 9th hole for both rounds on consecutive days. CAF was administered in combination with other ingredients including pterostilbene; an antioxidant which has been shown to improve cognitive functioning in mice (Chang et al., 2012), B vitamins, citric acid, sucralose and elevATP® (a plant extract associated with enhanced mitochondrial ATP production (Joy et al., 2016)). A standardised meal (340 kcal) including 42g carbohydrate, 12g fat and 24g protein was provided in both trials following the 9th hole. Total score (76.9 ± 8.1 vs. 79.4 ± 9.1, p = .039), greens in regulation (8.6 ± 3.3 vs. 6.9 ± 4.6, p = .035), and drive distance (239.9 ± 33.8 vs. 233.2 ± 32.4, p = .047) were statistically enhanced during the CAF condition compared with those during PLA, although no differences (p > .05) were found in fairways in regulation, putts per round or first putt distance. During a pre and post-round iron accuracy test, greens (target) hit and distance missed were significantly enhanced (p < .01) in the CAF trial compared to placebo. CAF also reported more energy after 9 holes (p = .025) but not significantly more after 18 holes (p > .05) compared to placebo whilst fatigue did not substantially change over 18 holes for CAF (p > .05) and almost doubled in placebo from pre to post-round.

The most recent caffeine and Golf performance study was conducted by Bristow (2016) who addressed one of the main limitations of previous research by administering caffeine in isolation (3 mg·kg^{-1}) pre-round and following 9 holes whilst involving both a laboratory testing phase measuring drive performance variables before and after an on-course round. A total of 11 male participants (age, 29 ± 7 years; BM, 85.5 ± 13.3 kg; handicap, 4.8 ± 3.7; daily caffeine intake, 318 ± 188 $mg \cdot day^{-1}$) were included in a randomised, counter-balanced crossover design. No significant differences ($p > .05$) in on course-variables were found between the caffeine and placebo trials. However ball speed and total distance both decreased from pre to post-round ($p < .05$) in the placebo trial whilst no differences were found in the caffeine trial which may indicate a difference in levels of fatigue.

Although it is difficult to compare these findings directly due to differences in performance variables measured, the non-standardised conditions and the combination of nutritional ingredients in which caffeine was administered, it appears that a caffeine supplement may attenuate fatigue towards the end of a round of golf whilst improving alertness/energy levels (Mumford et al., 2016; Stevenson et al., 2009). This may prevent a decline in some performance variables, particularly those associated with driving performance (Bristow, 2016; Mumford et al., 2016) although it cannot be dismissed that other nutritional ingredients contributed to these findings. Future research should consider replicating the conditions of existing studies whilst administering caffeine in isolation or in an alternative dosage which may provide more definitive results.

3.3 Carbohydrates

To date, the study by Stevenson et al. (2009) is the only to investigate the effects of carbohydrate consumption on Golf performance in the form of a sports drink including caffeine. As previously discussed, putting performance was enhanced particularly over the final 6 holes whilst players reported feeling more alert and relaxed over 18 holes in the sports drink trial. The sports drink (0.64 $g \cdot kg^{-1}$ of carbohydrate) was consumed pre-round (375 ml ≈ 24 g carbohydrate) and during holes six and twelve (187.5 ml ≈ 12 g carbohydrate). This protocol maintained euglycemia for the duration of the round although blood glucose fell by 0.29 $mmol \cdot l^{-1}$ to approximately 4.87 $mmol \cdot l^{-1}$ post-round with a significant main effect for time ($p < .001$). Furthermore self-ratings of mental fatigue, tiredness and hunger all showed a main effect for time ($p < .01$). Although this protocol established a period of no more than 1.5 hours between carbohydrate intake, the amount of carbohydrate consumed was significantly less than the lower recommendation by the ACSM (2016) of 30 $g \cdot hour^{-1}$ during extended exercise. This may have been a factor in why self-rated fatigue was not significantly different between trials. An area which was not considered by the authors was the carbohydrate type as defined by Glycemic Index (GI) rating. Stevenson et al. (2009) used glucose, a high GI source which enters the blood stream quickly in comparison to low GI sources (Philippou, 2016) which may be of benefit during sustained moderate to high intensity exercise (ACSM, 2016). However given the low exercise intensity experienced by participants in this investigation (heart rate, 95 ± 7 bpm; rating of perceived exertion (RPE), 12 ± 1), a low GI source may be more optimal in sustaining blood glucose through a more gradual release into the blood stream so that a rapid release would be unnecessary given that fat oxidation is higher during low intensity exercise. Sun, Wong, Chen, Huang and Hsieh (2011) found the consumption of a low GI meal before one hour of brisk walking (50 % $\dot{V}O_2max$) decreased carbohydrate oxidation ($p < .05$) in comparison to a high GI meal (60.8 ± 4.0 vs. 74.4 ± 4.7 g). This 'sparing' of carbohydrate may better sustain blood glucose concentration over a four hour round.

Although the objectives of other Golf nutritional research are distinct to the effects of carbohydrate, most of these investigations include designated time points where meals are consumed, commonly set as a standardised meal before play and a snack following the 9th hole. This protocol was first used by Hayes et al. (2009) in order to match participants usual nutritional habits whilst aiming to maintain euglycemia throughout the round although performance was not assessed. This was then used in more recent investigations by Mumford et al. (2016) who instructed participants to consume a meal (unrestricted) two hours before commencing play whilst a standard snack was provided following the 9th hole (including 42 g of carbohydrate) although blood glucose was not measured. In comparison Bristow (2016) used the same pre-round meal protocol although allowed participants the opportunity to consume their habitual snack following the 9th hole. This small difference in research design may be the reason why no significant differences in on-course performance variables were found in Bristow's study as it is possible that participants did not consume sufficient carbohydrates to sustain blood glucose levels thus preventing fatigue. However blood glucose was not measured, therefore it is only possible to speculate.

3.4 Phosphatidylserine

Jäger et al. (2007) published the only study to investigate the effects of phosphatidylserine (PS) supplementation on Golf performance. Phosphatidylserine is a component of cell membranes which when supplemented has been shown to reduce levels of plasma cortisol following exercise induced stress (Starks, Starks, Kingsley, Purpura, & Jäger, 2008) and mental stress (Komori, 2015). This may be ergogenic to Golf performance when cortisol (associated with psychological stress) is elevated when playing competitive Golf in comparison to non-competitive practice rounds (McKay, Selig, Carlson, & Morris, 1997). The study included 20 participants (age, 33 ± 8 years; BM, 77.6 ± 7.8 kg; handicap, 26.8 ± 7.5) who consumed either PS in the form of bar containing 200mg of PS and 20 grams of carbohydrate (n = 10) or an isolocaric placebo bar (n = 10) for 42 days following baseline tests until the day before follow up testing. The test involved participants hitting 20 shots to a target 135m in distance under timed conditions whilst perceived stress using a Visual Analogue Scale (VAS): 1 (low stress) to 10 (maximum stress), was rated following the series of shots. It was found that the number of on-target shots significantly ($p < .05$) increased from 8.3 ± 3.5 to 10.1 ± 3.0 in the PS trial whilst there was no improvement in the placebo trial (pre-test, 7.8 ± 2.4; post-test 7.9 ± 3.6). There was a trend ($p = .07$) for reduced stress levels (pre-test, 5.8 ± 2.0; post-test 4.0 ± 2.0) in the PS trial compared to no change for placebo. However, there are number of limitations in the design of this study including the selection of high handicap participants who are more likely to be inconsistent in performance compared to lower handicap players (handicap < 5). Higher handicap players have also been shown to have higher cortisol levels than elite players (handicap < 3) (Kim, Chung, Park, & Shin, 2009). Additionally the test examined only one facet of the game in a very short period of time (20 shots with 15 second intervals) which does not represent the conditions faced when playing a normal round of Golf.

Conclusion

Nutrition in Golf performance has received very little investigation in comparison to other scientific areas of the game primarily due to difficulties in standardising conditions. Most published research has focused on the effects of sport supplements on specific performance variables such as driving, putting, accuracy and levels of fatigue which has likely been driven by the commercial objectives of supplement manufacturers. Caffeine has been the most commonly investigated supplement although it has been combined with a range of other nutritional ingredients which make it difficult to identify direct effects. Nevertheless research has found improvements in on-course performance measures such as total score and greens in regulation in addition to psychological measures when consumed before and during play. The two primary physiological challenges arising over a round of golf; to maintain euhydration and euglycemia, have been extensively investigated in other sports resulting in optimal consumption strategies. Yet these strategies do not directly apply to Golf because of the variable conditions faced by players over an extended period of time whilst having to execute high level motor skill and cognitive tasks under pressure. A moderate consumption of carbohydrates (< 30 g·hour^{-1}) has been shown to offset the decline in blood glucose however it is not known whether a greater or more frequent consumption pattern prevents the increase in ratings of self-perceived fatigue found in most studies conducted using on-course rounds of golf. Furthermore golf played in a competitive environment may stimulate different physiological responses to non-competitive rounds which should be investigated to determine whether a different strategy is required. Finally in order to encourage future research on Golf nutrition, investigations should be repeatable allowing for small adaptations to meet different objectives whilst maximising real-life outcomes. However although standardised conditions are necessary to allow comparison between investigations, using on-course rounds of golf in a competitive environment best captures the variability players face whilst playing which is difficult to replicate in laboratory settings.

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‘The effect of HGI and LGI nutrition strategies on blood glucose and Golf performance statistics during competition’

This scientific investigation is intended for publication in the International Journal of Sport Nutrition and Exercise Metabolism (IJSNEM). The aim of this investigation was to offer new insights into performance nutrition in Golf covering topics including carbohydrate intake, hydration and metabolism. Nutrition in Golf performance is a relatively new area of interest which defines itself from other sports due to the range of conditions players may face over an extended period of time. This investigation is unique in being the first categorise carbohydrate intake by Glycemic Index rating whilst maximising real life application through the use of an independent tournament setting.

Abstract

The purpose of this study was to investigate the effects of two nutritional plans based on a high (HGI) and low (LGI) Glycemic Index (GI) rating on blood glucose (BG) and performance indicators during tournament rounds of Golf. Isocaloric meal plans of a HGI (GI = 79) and LGI (GI = 40) rating were consumed by six amateur players (age, 44 ± 16 years; height, 180.7 ± 5.8 cm; weight, 85.3 ± 10.2 kg; handicap 7.5 ± 3.4) between holes 3 - 6 and 12 - 15 during competitive member tournaments in a randomised crossover design. BG was measured pre (BG_{pre}), following 9 holes (BG_{dur}) and post (BG_{post}) round. Urine Osmolality (UO) was measured pre (UO_{pre}) and post (UO_{post}) round. Performance statistics including nett score (NS), fairways in regulation (FIR),

greens in regulation (GIR) and the total putts (PUTTS) were recorded each round. A 2 x 3 (condition x time) repeated measures ANOVA revealed no significant difference ($p > .05$) in BG samples between trials or time points; $BG_{pre} = 6.0 \pm 1.1$ vs. 5.9 ± 1.3, $BG_{dur} = 5.7 \pm 0.5$ vs. 5.5 ± 0.3, $BG_{post} = 5.4 \pm 0.5$ vs. 5.3 ± 0.6 mmol·l^{-1}, in the LGI and HGI trials respectively. Hydration status was maintained to < 2 % loss in body mass and to < 700 mOsm·kg^{-1} post round in both trials during warm conditions (20.3 ± 2.9 ˚C). Paired samples *t*-tests found no significant differences ($p > .05$) in performance statistics between trials although there was a tendency for better scores in NS, GIR and PUTTS during the LGI trial. Both HGI and LGI meal plans maintain euglycemia when consumed frequently over 18 holes although there is no evidence to suggest that one enhances or prevents a decline in performance more than the other.

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Abbreviations

BG – Blood Glucose ($mmol \cdot l^{-1}$)
BM – Body Mass (kg)
FIR – Fairways in Regulation
GI – Glycemic Index
GIR – Greens in Regulation
GL – Glycemic Load
HC – Golf Handicap
HGI – High Glycemic Index (> 70 GI rating)
LGI – Low Glycemic Index (< 55 GI rating)
PUTTS – Total number of Putts
NS – Total number of strokes relative to HC and CSS
CSS – Competition Standard Scratch
T_{pre} – Testing pre-round
T_{dur} – Testing following the 9th hole
T_{post} – Testing following the 18th hole
UO – Urine Osmolality ($mOsm \cdot kg^{-1}$)

1. Introduction

Despite that the game of Golf is a non-contact and relatively low intensity sport (Stevenson, Allison, & Hayes, 2009), the extended duration of 18 holes (a round) lasting anywhere from three to six hours whilst covering distances in excess of 10 km and playing in a competitive environment will challenge physiological and cognitive functioning (M. F. Smith, 2010). The topic of nutrition in Golf performance has received little investigation in comparison to the biomechanics and psychology of the game (Farrally et al., 2003). This is despite an abundance of research supporting specific nutritional strategies (ACSM, 2016; Burke, Hawley, Wong, & Jeukendrup, 2011) to be consumed during competition for optimal performance in a range of other sports.

Competitive golf requires high-level motor skill to perform repeated swings of variable intensity from maximal velocity drives to controlled putting stokes and cognitive skill to aid decision making which is tested on every shot (Mumford et al., 2016; Smith, 2010). Hypoglycemia can lead to a lack of focus, irritation and poor decision making (Smith, 2010) and higher ratings of self-perceived fatigue (Welsh, Davis, Burke, & Williams, 2002). Furthermore dehydration can also increase ratings of self-perceived fatigue (Smith, Newell, & Baker, 2012), impair cognitive performance such as distance perception (Maughan, Shirreffs, & Watson, 2007; Smith et al., 2012) and impair motor skill in the form of dynamic postural stability (Derave, Clercq, Bouckaert, & Pannier, 1998).

Research indicates that a specific nutritional plan is required in order to maintain euglycemia over 18 holes (Hayes, van Paridon, French, Thomas, & Gordon, 2009; Stevenson et al., 2009). This may be achieved by a sufficient carbohydrate intake although the blood glucose (BG) response may vary depending on the type of carbohydrate, the macronutrient composition of the meal and/or the frequency of consumption (ACSM, 2016). Likewise research has found that a specific fluid intake is required to maintain euhydration. Dehydration has been shown to be prevalent even among elite level college players (Magee, Gallagher, & McCormack, 2016).

In the UK it is not uncommon to find Golf Clubs well stocked with high energy sports drinks and confectionary in which the majority are classified as high glycemic index (HGI) foods. This becomes the restricted choice of players who choose not to bring foods with them to consume during play. On the other hand, many amateur players choose not to consume foods during their round whilst a minority of players consume foods such as fruit, nuts and sandwiches in which some of these may be classified as low glycemic index (LGI) foods. The primary aim of this study is to investigate whether nutritional plans based on a HGI and LGI rating consumed during competitive rounds of Golf maintain euglycemia and whether significant differences exist in a range of performance variables between the two plans. The hypothesis is a LGI meal plan is preferred to a HGI plan in that BG is stabilised for a longer period. The secondary aim is to assess whether a set amount of fluids (1.5 litres) consumed over 18 holes maintains euhydration and whether hydration status as measured by urine osmolality (UO) is correlated with performance variables. The hypothesis is a regular consumption of fluids over 18 holes maintains euhydration during average UK summer temperatures.

2. Methods

2.1 Participants

A total of 45 members of Eaton Golf Club, Chester were invited to participate via email, following permission from the leadership board at the Golf Club and the Faculty of Medicine, Dentistry and Life Sciences Research Ethics Committee at the University of Chester (appendix 1). All invited members had an active club handicap of ≤ 15.4. A response was received from 15 members of whom only 8 were available to participate in 2 of the 3 allocated trial dates. Prior to the first trial date, 2 of these members had to withdraw due to injury or other commitments leaving a total of 6 participants. A Health Screen form (appendix 2) confirmed none of the six participants had high blood pressure, diabetes, food allergies or any injuries which would exclude them from taking part. Additionally each participant completed a Consent form (appendix 3) and Golf History form (appendix 4). The participant's baseline measurements are shown in Table 2.1.

Table 2.1 Participant Baseline Data

Subject	Age (years)	Handicap	Height (cm)	Body Mass (kg)	Rounds per month	Years Playing
1	38	9.4	175	91.4	8	12
2	63	5.7	181	78.8	16	52
3	27	4.9	193	105.0	12	15
4	26	5.1	180	82.8	12	15
5	51	14.4	178	74.0	8	20
6	58	5.5	177	80.0	16	35
Mean	44	7.5	181	85.3	12	25
SD	16	3.4	6	10.2	3	14

2.2 Design

In a randomised repeated measures crossover design each participant consumed both the HGI and LGI meal plans (appendix 5) during two separate competitive rounds (trials). The participants were given the choice to play in any two of three allocated trial dates in the months of June and July which were separated by two week intervals. The competitive rounds were played as part of club scheduled individual stroke-play competitions which were open to all members of Eaton Golf Club (18 Holes, Par 72, SSS 73, 6714 yards). Each competition had a £2 entry fee with prizes in the form of golf shop vouchers awarded to the top three places (organised by Eaton Golf Club). The participants were also given the option of playing with members who were not participants in the study but were asked to tee off at a similar time in both rounds. During each trial date there were three test points; approximately 30 minutes before tee off (T_{pre}), immediately following the 9th hole (T_{dur}) and immediately following the 18th hole (T_{post}). The dependent variables measured during each test point included;

T_{pre}: BM_{pre} (Body Mass), BG_{pre}, UO_{pre}

T_{dur}: BG_{dur} only

T_{post}: BM_{post}, BG_{post}, UO_{post} and performance statistics*; NS, FIR, GIR and PUTTS.

**Performance Statistics definitions;*

Nett Score (NS) - the total number of shots over 18 holes less handicap (HC) and adjusted for each competitions standard scratch (CSS).

Fairways in Regulation (FIR) – the number of holes the ball finished on the fairway from playing a tee shot on par 4 and par 5 holes. There are a total of 14 par 4 and par 5 holes at Eaton Golf Club.

Greens in Regulation (GIR) –the number of holes the ball finished on the surface of the green after a tee shot on a par 3, after a second shot (or less) on a par 4, or after a third shot (or less) on a par 5 hole (Mumford et al., 2016).

Total Putts (PUTTS) – the total number shots taken from the surface of the green.

Competition Standard Scratch (CSS) – the adjusted par of the course relative to the players handicaps and scores returned during a competition.

The diagram in Figure 2.1 summaries the research design.

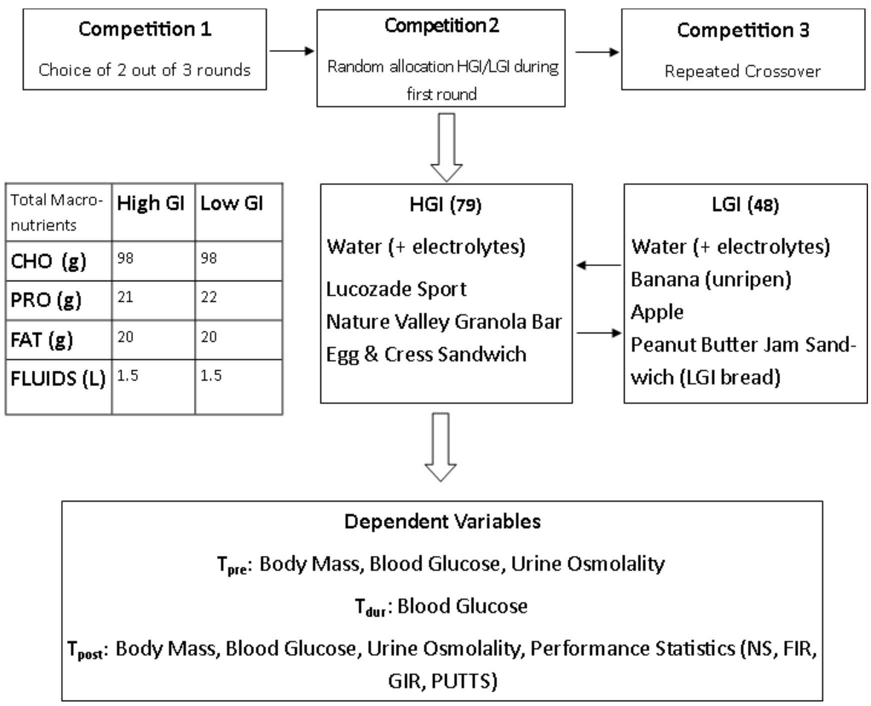

Figure 2.1 Research Design

2.3 Procedures

All participants had been a member of Eaton Golf Club for at least one year hence were familiar with the course and competition rules. They were instructed to use the same equipment (golf clubs and balls) during the two rounds. Participants were required to abstain from alcohol and caffeine containing food/drink during the evening and morning before each round as both were identified as potential confounding variables. Additionally participants were required to consume an identical breakfast which was recorded in a food diary (appendix 6) including carbohydrates and at least 500 ml of water, 1.5 hours before each round. The aim was to ensure participants achieved euhydration and euglycemia before commencing play whilst ensuring consistency between rounds. The food diaries were not assessed as part of this study but were used to remind participants to consume an identical breakfast before their second round. These procedures were similar to those employed by Mumford et al. (2016) and Bristow (2016) who required that participants consumed a meal two hours before commencing play and arrive hydrated before playing Golf in a competitive setting to investigate the effects of a nutritional supplement on Golf performance.

Participants were required to report to the clubhouse 30 minutes before their scheduled start time. Firstly, a urine sample (UO_{pre}) was obtained which was analysed using a handheld Osmometer (Osmocheck, VITECH, West Sussex, United Kingdom). A measurement of < 700 mOsm·kg^{-1} was assumed euhydrated whilst a measurement of > 900 mOsm·kg^{-1} was assumed dehydrated (ACSM, 2007). BM_{pre} was measured to the nearest 0.1 kg with footwear removed using Seca 813® scales (Seca, Hamburg). A finger-prick blood sample was collected and analysed using an Accutrend Plus Meter® (Roche Diagnostics). A BG measurement between the range of 4.0 to 8.0 mmol·l^{-1} was assumed normal (Frayn, 2010) which allowed for the postprandial rise in BG following the breakfast consumed at least 1.5 hours before the BG_{pre} sample and the consumption of meal plans during play. Hypoglycaemia was recognised as a measurement of < 4.0 mmol·l^{-1} (Cox, Gonderfrederick, Schroeder, Cryer, & Clarke, 1993). Following BG_{pre}, participants were randomly allocated either the HGI or LGI meal plan before their first round and instructed to consume approximately half the foods (including carbohydrate containing drinks) between holes 3 and 6 and half between holes 12 and 15 and consume all water provided ad libitum. The researcher reminded participants to follow this protocol before the 1st hole and following BG_{dur} testing although this was not monitored during play. An adapted scorecard was provided to allow the participants to record performance statistics (NS, FIR, GIR, PUTTS) in addition to a separate competition scorecard issued by the competition organiser.

Immediately after completing the 9th hole, participants briefly returned to the clubhouse for BG_{dur} testing. The clubhouse was located next to the 10th hole which minimised disruption and maintained the pace of play. Final testing commenced immediately following completion of the 18th hole including $UO_{post,}$ BM_{post} and BG_{post} whilst the performance statistics scorecard was collected. Weather conditions including ambient temperature and wind speed (maximum and minimum) and rainfall were recorded throughout the trial dates.

The protocols followed for UO, BG and BM testing are outlined in appendix 7.

2.4 HGI / LGI Meal Plans

The HGI and LGI meal plans were selected using food and drink which were affordable, easy to prepare, obtain and consume on the golf course whilst providing a balanced macronutrient composition and a tested GI rating (Aston et al., 2010). Meeting these criteria would encourage the consumption of such meal plans should results indicate significant improvements in performance whilst enabling their use in future research. See appendix 5 for an itemised list of the food/drink included in each plan.

A macronutrient comparison between plans is outlined in Table 2.4. Macronutrient data was obtained from individual food product labels whilst GI ratings were obtained from the Diogenes GI Database (Aston et al., 2010). LGI foods were classified as a GI rating of ≤ 55 whilst HGI foods were classifed as a rating ≥ 70 (Brand-Miller, Foster-Powell, Colagiuri, & Burani, 2003). The GI is a ranking of carbohydrate containing foods is based on how quickly blood glucose concentration is elevated following consumption (Philippou, 2016). The GI of the meal plans were calculated as a weighted average of GI values based on the carbohydrate content of individual foods (Philippou, 2016). Both plans were identical in macronutrient composition (± 1 gram) and were isocaloric. Total carbohydrate content represented approximatley 57% of total kcal which met the Scientific Advisory Committee on Nutrition (SACN, 2011) daily intake recommendations. The ACSM (2016) does not provide a recommended carbohydrate intake during low intensity exercise. The total carbohydrate amount of 98g was more than double than that used by Stevenson et al. (2009) (based on a 75kg BM) who found a signifigant ($p = .001$) increase in mental fatigue and tiredness over 18 holes.

Table 2.4 Macronutrient Comparison

Macronutrient	LGI	HGI	Difference
Carbohydrate (g)	98	98	0
Protein (g)	21	22	1
Fat (g)	20	20	0
Calories (Kcal)	686	674	12
Fluids (L)	1.5	1.5	0
Glycemic Index*	40	79	39
Glycemic Load*	11	22	11

*obtained from (Aston et al., 2010)

Glycemic Load (GL) measures the overall glycemic impact of a food and is the product of a food's GI and the amount of carbohydrate it provides (Philippou, 2016). A low GL rating is classified as ≤ 10 whilst a high GL rating is ≥ 20 (Brand-Miller et al., 2003). The LGI meal plan was marginally above a low GL rating whilst the HGI plan met the criteria of a high GL rating. GL was not the focus of this investigation.

2.5 Statistical Analysis

Data is presented as mean ± SD for all normally distributed dependent variables. Statistical analysis was performed using SPSS version 25.0 (IBM, Seattle, WA). Each dependent variable was tested for normality using the Shapiro-Wilk procedure before selecting the appropriate test. Paired samples *t*-tests were used to examine the mean differences between trials in performance statistics (NS, FIR, GIR, PUTTS) and between UO_{pre} and UO_{post}. A two way repeated measures ANOVA with three levels assessed the mean differences in BG. If a significant difference was found, paired *t*-tests with

Bonferroni corrections were used to identify where the differences lie. Additionally, UO and performance statistics were analysed for a statistically significant relationship using a Pearsons Product Moment test. The level of statistical significance was set at $p < .05$ for all null hypothesis testing.

3. Results

3.1 Weather Conditions

Conditions during each trial date were similar with no rainfall recorded, see Table 3.1. Ambient temperatures were approximately average (20.3 ± 2.9 ˚C) for the month of July (Metoffice, 2018) with 5 ˚C range in maximum temperatures. Average wind speed was 7.8 ± 2.1 mph with a range of 2 mph in maximum wind speed which was classified as a light to gentle breeze on the Beaufort Wind Force Scale.

Table 3.1 Meteorological Trial Data

Trial Date	Conditions	Rainfall (cm)	Max - Min Temperature (˚C)	Max - Min Wind Speed (mph)
1	**Sunny**	**0**	**22 - 17**	**9 - 7**
2	**Sunny**	**0**	**25 - 20**	**9 - 4**
3	**Light Cloud**	**0**	**20 - 18**	**10 - 8**

3.2 Hydration Status

Each participant maintained BM within a 2% loss, see Table 3.2. One participant commenced the HGI trial with a UO_{pre} sample of 910 mOsm·kg^{-1} indicating dehydration. However sufficient fluids consumed during the round returned the participant to a euhydrated state (UO_{post} = 430 mOsm·kg^{-1}). All other participants were classified as euhydrated before and after both trials (UO_{pre} and UO_{post} < 700 mOsm·kg^{-1}). There was no significant difference in UO_{pre} and UO_{post} within trials or between trials although there was a tendency for UO to decrease within trials (HGI; UO_{pre} = 540 ± 271, UO_{post} = 318 ± 185 mOsm·kg^{-1} (p = .031), LGI; UO_{pre} = 400 ± 228, UO_{post} = 357 ± 188 mOsm·kg^{-1} (p = .353)). No significant correlations (p > .05) were found between UO_{pre} or UO_{post}

and performance statistics (NS, FIR, GIR, PUTTS). The strongest correlation was found between UO_{post} and PUTTS ($r = -.428$, $r^2 = .18$; $p = .217$).

Table 3.2 Body Mass and Urine Osmolality

Participant / Test point	HGI BM (kg)	LGI BM (kg)	HGI UO ($mOsm \cdot kg^{-1}$)	LGI UO ($mOsm \cdot kg^{-1}$)
1 Pre	90	91.4	490	300
1 Post	90	91	350	390
% Change	**0.0%**	**-0.4%**		
2 Pre	78.8	79.8	910	370
2 Post	78.6	79.4	430	330
% Change	**-0.3%**	**-0.5%**		
3 Pre	104.8	105	690	660
3 Post	104.2	104.8	610	640
% Change	**-0.6%**	**-0.2%**		
4 Pre	82.8	84.2	100	120
4 Post	82.4	83.4	100	130
% Change	**-0.5%**	**-1.0%**		
5 Pre	74	72.8	600	690
5 Post	73.8	73	230	470
% Change	**-0.3%**	**0.3%**		
6 Pre	80	80	450	260
6 Post	78.8	79	190	180
% Change	**-1.5%**	**-1.3%**		

3.3 Blood Glucose

BG samples collected at each time point in both trials were normal for all participants ($4 \leq BG \leq 8$ $mmol \cdot l^{-1}$, see appendix 8). A 2 x 3 (condition x time) repeated measures ANOVA revealed no significant difference in BG between the HGI and LGI meal plans. Average LGI samples ($BG_{pre} = 6.0 \pm 1.1$, $BG_{dur} = 5.7 \pm 0.5$, $BG_{post} = 5.4 \pm 0.5$ $mmol \cdot l^{-1}$) were not significantly ($p > .05$) different from HGI samples ($BG_{pre} = 5.9 \pm 1.3$, $BG_{dur} = 5.5 \pm 0.3$, $BG_{post} = 5.3 \pm 0.6$ $mmol \cdot l^{-1}$) whilst there were no significant time x condition interaction ($p > .05$). In both trials BG decreased from pre-round to the 10th hole by approximately 0.3 mmol•l^{-1}. From the 10th hole to finishing the 18th hole, blood glucose decreased by approximately the same amount (0.3 mmol•l^{-1}) but remained significantly above the hypoglycaemia threshold. The total fall in blood glucose from BG_{pre} to BG_{post} was approximately 10% in both trials.

3.4 Performance Statistics

During the HGI trial, one NS and one PUTTS statistic were excluded from analysis whilst one PUTTS statistic was excluded from the LGI trial leaving *n* = 5. This was due to either a participant not returning a score on one hole or misreporting the PUTTS statistic. Paired samples *t*-tests revealed no significant ($p > .05$) difference in NS, FIR, GIR or PUTTS between the LGI and HGI trials. During the LGI trial, NS was lower (73.0 ± 3.2 vs. 73.2 ± 2.2, $p = .91$) and PUTTS was lower (30.6 ± 2.9 vs. 31.6 ± 4.5, $p = .756$) whilst GIR was higher (7.3 ± 4.2 vs. 7.0 ± 3.6 $p = .82$) than during the HGI trial respectively. On the other hand, only FIR was higher (7.2 ± 2.2 vs. 6.7 ± 4.1, $p = .67$) in the HGI trial than during the LGI trial respectively.

4. Discussion

To the researcher's knowledge, this was the first study to investigate the effects of two nutritional plans based on a HGI and LGI rating on Golf performance and physiological variables. Furthermore it is only the second nutritionally focused study to use on-course tournament rounds of golf within the research design (Mumford et al. (2016)). Despite difficulties in standardising conditions (Stevenson et al., 2009), this design captures the competitive environment that both amateur and professional players' experience which is difficult to replicate in laboratory settings.

Weather conditions were similar during each trial date with around average (20.3 ± 2.9 ˚C) temperatures for the month of July and light to gentle wind speeds. Given the two week period between trials, this was unanticipated and was the primary reason for using CSS adjusted NS (capturing the variability in playing conditions) as opposed to using NS alone. Therefore it may be assumed that these conditions did not restrict the participant's ability to play to or better their handicap (NS), limit scores in FIR, GIR or PUTTS or affect BG between trials. Conditions were similar to Bristow (2016) who used an on-course round to investigate the effects of a caffeine supplement consumed before and during play on performance (mean temperatures, 20.8 and 21.7 ˚C; mean wind speed, 5.4 and 7.5 mph). However in a similar study conducted by Mumford et al. (2016) in the USA, temperatures were significantly greater (36 ˚C and 18 mph winds) although remained similar between trials due to rounds being played on consecutive days. On the other hand Stevenson et al. (2009) used a laboratory simulated round of golf as designed by Hayes et al. (2009) in investigating the effects of a caffeine and carbohydrate drink on putting performance and measures of fatigue. Walking between shots was conducted on a treadmill in temperatures similar to this investigation (20 - 24 ˚C) although wind speed was not applicable in an enclosed environment. Therefore it is difficult to compare results given the variability in playing conditions and the limited amount of other studies conducted in this area.

The ACSM (2007) recommends the consumption of sufficient fluids during exercise to limit sweat losses to < 2% loss in BM with the addition of sodium when sweat rates are high. The fluids consumed in each meal plan (1.5 litres with added sodium) met the ACSM guidelines to maintain hydration status in all participants with only one participant increasing BM by 0.3 % indicating surplus fluid consumption. This would indicate that the fluids consumed matched the sweat rates of most participants in warm conditions. However despite all participants being classified as euhydrated post round (UO < 700 $mOsm \cdot kg^{-1}$) the amount which UO decreased from pre to post round varied which was likely due to all participants receiving the same amount of fluids irrespective of BM and sweat rates. In comparison Stevenson et al. (2009) administered 750ml of fluids (10 $ml \cdot kg \cdot round^{-1}$) during a simulated round which maintained euhydration (UO_{pre} = 623 ± 143, UO_{post} = 515 ± 198 $mOsm \cdot kg^{-1}$). No significant relationship was found between UO_{pre} or UO_{post} and performance statistics which indicates that lower UO levels do not improve performance if already euhydrated.

Participants maintained euglycemia in both the HGI and LGI trials (during and post round) with no significant differences observed between trials. This suggests that there is no difference between plans when consumed frequently (between holes 3 - 6 and 12 - 15) in maintaining euglycemia over 18 holes. BG samples were insignificantly lower at each test point in the HGI trial compared to the LGI trial although this may have been due to small differences in conducting the BG_{pre} sample relative to when participants consumed their pre-round breakfast. The change in BG from pre-round to the 10th hole (- 0.3 mmol·l^{-1}) and from the 10th hole to following the 18th hole (- 0.3 mmol·l^{-1}) followed a similar pattern to that found in other studies. Hayes et al. (2009) found BG fell by approximately 0.3 mmol·l^{-1} over the first 9 holes (from 5 to 4.7 mmol·l^{-1}) which then stabilised following a snack on the 9th hole during an on course round. Stevenson et al. (2009) found BG decreased by 0.29 mmol·l^{-1} over 18 holes (BG_{pre} = 5.16 ± 0.56, BG_{post} = 4.87 mmol·l^{-1}) during a simulated round despite the consumption of a carbohydrate (0.64 g·kg^{-1} body mass (BM)) and caffeine isotonic sports drink (HGI) before the round (5 ml·kg^{-1} BM) and during holes 6 and 12 (2.5 ml·kg^{-1} BM). Although these results are comparable to this study, participants did not have to carry their clubs, walked at a constant speed, were not in a competition and spent 5 ± 2 minutes stationary following the completion of each hole for testing. Therefore this may not reflect the true physical demands of competitive golf and likely resulted in a lower overall exercise intensity which would underestimate the BG response relative to the conditions used in this study. The amount of carbohydrate in each meal plan in this study was approximately double (1.31 g·kg^{-1} BM based on a 75kg male) the amount included in the isotonic sports drinks used by Stevenson et al. (2009) which may have contributed to a higher BG concentration post round (LGI BG_{post} = 5.38 ± 0.55, HGI BG_{post} = 5.27 ± 0.57 vs. sports drink BG_{post} = 4.87 mmol·l^{-1}). The decline in BG from BG_{pre} to BG_{post} was higher in this investigation than in Stevenson et al. (- 10.0 vs. - 5.6 %) which may have been expected given that there is an increasing insulin response when BG exceeds 5 mmol·l^{-1} (Frayn, 2010).

There were no significant differences in any of the performance statistics (NS, FIR, GIR, PUTTS) between trials. However it is not possible to conclude whether this was related to the BG response or UO level which also showed no significant differences between trials. This may have been due to the small sample size. There was however a tendency for improved results during LGI trial which showed marginally better scores in three of the four performance markers. Also of interest was that the two best scores (69 and 69) both occurred during the LGI trial in which one participant won the overall club competition with other participant finishing tied 2nd. Given that this is the only study to investigate the effects of nutritional plan based on GI ratings on golf performance statistics, it is not possible to compare results directly. Stevenson et al. (2009) found that the consumption of an isotonic sports drink containing carbohydrate (glucose which has GI rating of 100 (HGI)) with caffeine pre round and during holes 6 and 12 improved 2 and 5 meter putting performance (as measured by total distance missed) during the final 6 holes of a simulated round. However the authors conclude that it was not possible to distinguish between the effects of caffeine and glucose.

4.1 Limitations

The sample size of six participants was significantly less than the initial target of 12, therefore reducing the strength of statistical analysis. This low sample size may have been due to the research design which included participants from a single golf club to enable the study to be conducted in real tournament settings with multiple competition dates. Additionally initial invitations were sent to category one and two handicapped players (HC < 9.5) to improve scoring consistency between rounds although the total number of members in these categories was relatively small compared to higher categories. On the other hand this sample size was similar to Smith et al. (2012) who investigated the effects of mild-dehydration on golf performance including 7 participants (HC, 3.0 ± 1.2).

In order to simplfy the preparation of both meal plans, total foods and fluids were identical for all participants in contrast to allocating based on BM as used by Stevenson et al. (2009). This may have caused a signifcant variation in BG_{pre}, BG_{dur} and BG_{post} and UO_{pre} and UO_{post} samples when the BM of participants varied widely (85.3 ± 10.2 kg) such that those with a higher BM received relatively less kcal and fluids which may have impacted performance. In support of this there was a large range in UO_{pre} between participants (810 $mOsm \cdot kg^{-1}$).

An important aim of this study was to conduct a realistic intervention using common meal plans. Although it is unlikely players would consume foods containing only one macronutrient over the course of a round, an intervention based on consuming only carbohydrates of a HGI or LGI rating may result in more definitive results. It was not possible to identify whether carbohydrates alone resulted in the BG and performance responses observed when it is likely that the fat and protein content of the meal plans effected results. A potential method that future investigations in this area can maintain a 'real-life' research design whilst conducting a carbohydrate only intervention is by including an additional trial which observes participants habitual food and fluid intake before and during play. Furthermore future research should consider recording additional performance markers such as distance perception tests as used by Smith et al. (2013) which represent decision making ability and self-rated mood questionnaires which are an indicator of mental fatigue as used by Stevenson et al. (2009). Additional measures of short game performance (only measured by PUTTS in this study) such as the success rate of making a par despite missing the green (scrambling, (PGATOUR, 2018)) may be a measure of resilience which has been shown to be a predictor of fatigue in other environments (Losoi et al., 2015).

5. Conclusion

This study was the first to assess the effects of two nutritional plans based on a HGI and LGI rating, consumed during competitive rounds of golf on a range of performance variables. Both plans were based on commonly consumed food and drink which were accessible, affordable and contained sufficient carbohydrate to maintain euglycemia during play. It was found that both the LGI and HGI meal plans equally maintained BG and hydration to within optimal levels for sports performance. A frequent consumption of adequate carbohydrates and fluids appears to be more important than the type of carbohydrate in maintaining these physiological variables suggesting that players may benefit from a more regular consumption pattern as opposed to a limited snack after 9 holes. Whether a specific GI meal type enhances or prevents a decline in Golf performance requires further investigation by measuring additional markers of performance and using a larger sample of low handicap players.

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Appendix 1 (Ethical approval Letter)

See in soft bound copy.

Appendix 2 (Health Screen Form)

University of Chester

Pre-test Questionnaire

The effect of High GI and Low GI nutrition strategies on Golf performance during competition

Researcher *: Michael Robinson*

Name:_________________________________ Test date:________________

Contact number:____________________________ Date of birth:___________

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1. Has your doctor ever said that you have a heart condition *and* that you should only perform physical activity recommended by a doctor? YES/NO
2. Do you feel pain in the chest when you perform physical activity? YES/NO
3. In the past month, have you had chest pain when you were not performing physical activity? YES/NO
4. Do you lose your balance because of dizziness *or* do you ever lose consciousness? YES/NO
5. Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by playing? YES/NO
6. Is your doctor currently prescribing drugs for blood pressure or a heart condition? YES/NO
7. Do you have any food allergies or metabolic conditions (e.g. Lactose intolerance, Celiac disease)? YES/NO
8. Have you injured your hip, knee or ankle joint in the last six months? YES/NO
9. Are you diabetic or have been classified as pre-diabetic? YES/NO
10. Do you know of any other reason why you should not participate? YES/NO

Thank you for taking your time to fill in this form. If you have answered ‘yes’ to any of the above questions, unfortunately you will not be able to participate in this study.

Appendix 3 (Participant Consent Form)

University of Chester

Title of Project: The effect of High GI and Low GI nutrition strategies on Golf performance during competition

Name of Researcher: Michael Robinson

Please initial box

1. I confirm that I have read and understand the below documents for the above study and have had the opportunity to ask questions; ☐

- Participant Information Sheet
- Measurement Protocols
- Nutrition Plans
- Participant Instructions

2. I confirm that I have read and completed the Health Screen and Golf History forms for the above study and have had the opportunity to ask questions. ☐

3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

4. I agree to take part in the above study. ☐

____________________	____________________	____________________
Name of Participant	Date	Signature
Michael Robinson	________	________
Researcher	Date	Signature

1 for participant; 1 for researcher

Appendix 4 (Golf History Form)

University of Chester

Golf History Form

The effect of High GI and Low GI nutrition strategies on Golf performance during competition

Researcher *: Michael Robinson*

Name:_________________________________ Date:________________

The following information will be used to obtain average demographical information for the project. Please answer the following questions to the best of your knowledge:

11. Age

12. Height

13. Weight

14. Exact Handicap

15. Average number of rounds played per month

16. Years playing

Thank you for taking your time to fill in this form.

Appendix 5 (Meal Plans)

Foods	Size	Flavour/Variety	CHO (g)*	PRO (g)*	FAT (g)*	Calories (Kcal)*	CHO Contribution (%)	Glycaemic Index**	Meal GI***	Glycaemic Load**
Nutrition Plan 1 (High GI)										
Lucozade Sport	500ml	Orange	33	0	0	140	33.7%	95	32	6
Nature Valley Granola Bar	42 grams	Oats and Honey	27	3	7	192	27.6%	70	19	46
Sainsbury's Egg & Cress Sandwich	183 grams	Wheatgerm Bread	38	18	13	346	38.8%	72	28	13
Water + HIGH5 Electrolyte tab	1 Litre	Berry	0	0	0	8	0.0%	0	0	0
		Total	**98**	**21**	**20**	**686**	**100.0%**		**79**	**22**
Nutrition Plan 2 (Low GI)										
1 Medium Banana	150g	Unripe	35	2	0	154	35.7%	40	14	9
1 Medium Apple	133g	Gala	16	1	0	71	16.3%	38	6	4
Peanut Butter	30g	Smooth	4	8	15	185	4.1%	23	1	5
2 Slices Vogel's Bread	83g	Soya & Linseed	33	11	5	216	33.7%	40	13	16
Strawberry Jam	15g	Strawberry	10	0	0	40	10.2%	51	5	11
Water + HIGH5 Electrolyte tab	1.5 Litre	Berry	0	0	0	8	0.0%	0	0	0
		Total	**98**	**22**	**20**	**674**	**100.0%**		**40**	**11**

* Macronutrient values obtained from individual product information labels

**GI/GL ratings obtained from Ashton et al. (2010)

*** Calculated as a weighted average of cabohydrate content

Appendix 6 (Food Diary)

Participant Name: …………………………………………………..
To be completed on the morning of Round 1
Please ensure to list all foods and drinks consumed up to arriving at the golf club.

Breakfast (only decaf tea/coffee permitted)

Foods/Drinks	Quantity	Time
e.g. Hovis Brown Bread	*2 slices*	*8.00am*
e.g. Water	*500ml*	*8.00am*

Appendix 7 (Measurement Protocols)

Blood glucose, urine osmolality and body weight testing will be performed at three different time points on the day of each round (pre, during (after 9 holes) and post (after 18 holes)). Tests will be carried out in accordance with the University of Chester policy on blood, saliva and urine handling.

Blood Glucose Testing

Equipment required:

- Accutrend® Plus Meter
- BM-Accutest® Glucose Strips
- Accutrend® Sate T Pro Plus disposable lancets
- Accutrend® Control G solution
- Sharps Bin
- Yellow Clinical Waste Bag
- Protective Disposable Gloves
- Protective Disposable Apron
- Alcohol Swabs
- Sterile Cotton Tissues
- Waterproof Dressing
- Milton Fluid
- Washable Floor

Procedure:

1. Experimenter and subject should wash and dry hands thoroughly.
2. Experimenter must wear protective gloves and apron throughout the entire procedure.
3. Clean the subject's fingertip/forearm with an alcohol swab and dispose of alcohol swab in the yellow clinical waste bag.
4. Prepare the finger pricker according to the manufacturer's instructions.
5. Insert test strip into the meter. Ensure that the code on the display matches the code number on the strip container, according to the manufacturer's instructions.
6. Place the finger pricker on the fingertip pressing down firmly to release the lancet.
7. Squeeze the finger/forearm gently to reveal a drop of blood
8. Touch the blood drop to the front edge of the test strip, according to the manufacturer's instructions.
9. The blood glucose measurement should appear on the screen in 5 seconds.
10. Carry out a plausibility check after glucose measurement, according to the manufacturer's instructions.
11. Record result.

12. Subject may wipe finger/forearm with a sterile cotton tissue and dispose of it in the yellow clinical waste bag provided.
13. Remove the test strip and dispose of it in the sharps bin provided.
14. Remove the lancet from the finger pricker and dispose of it in the sharps bin provided.
15. Check that the subject has stopped bleeding.
16. Cover any wounds with a waterproof dressing

Urine Osmolality Testing
Equipment required:

- Osmocheck® Handheld Osmometer
- 30 ml Sterilin Container
- Yellow Clinical Waste Bag
- Protective Disposable Gloves
- Milton Fluid

Procedure:

- Provide subject with a 30ml sterile urine sample container.
- Instruct subject to wash hands before and after providing sample.
- Instruct subject to provide a mid-flow sample.
- Wear disposable gloves and apron throughout testing sample.
- Insert sample into Osmocheck® Handheld Osmometer.
- Record result and dispose of sample and container into clinical waste bag.

Body Weight Measurement
Equipment: Clinically Calibrated Scales
Procedure: Participants should be instructed to remove footwear and empty pockets before being weighed.

Appendix 8 (Raw Data)

Table 1. Subject Baseline Data

Name	**Age**	**Handicap**	**Height**	**Weight**	**Rounds per month**	**Years Playing**
1	38	9.4	175	91.4	8	12
2	63	5.7	181	78.8	16	52
3	27	4.9	193	105	12	15
4	26	5.1	180	82.8	12	15
5	51	14.4	178	74	8	20
6	58	5.5	177	80	16	35
Mean	43.8	7.5	180.7	85.3	12.0	24.8
SD	15.8	3.4	5.8	10.2	3.3	14.3

Table 2. HGI and LGI trial pre/post round Weight (kg)

Name	**HGI**	**LGI**
1 Pre	90	91.4
1 Post	90	91
% Change	**0.0%**	**-0.4%**
2 Pre	78.8	79.8
2 Post	78.6	79.4
% Change	**-0.3%**	**-0.5%**
3 Pre	104.8	105
3 Post	104.2	104.8
% Change	**-0.6%**	**-0.2%**
4 Pre	82.8	84.2
4 Post	82.4	83.4
% Change	**-0.5%**	**-1.0%**
5 Pre	74	72.8
5 Post	73.8	73
% Change	**-0.3%**	**0.3%**
6 Pre	80	80
6 Post	78.8	79
% Change	**-1.5%**	**-1.3%**

Table 3. LGI trial pre/post round urine osmolality (mOsm/kg)

Subject	**Pre LGI**	**Post LGI**
1	300	390
2	370	330
3	660	640
4	120	130
5	690	470
6	260	180

Table 4. HGI trial pre/post round urine osmolality (mOsm/kg)

Subject	**Pre HGI**	**Post HGI**
1	490	350
2	910	430
3	690	610
4	100	100
5	600	230
6	450	190

Table 5. LGI trial pre/during/post round blood glucose (mmol/L)

Subject	**Pre LGI**	**During LGI**	**Post LGI**
1	7.9	5.6	5.4
2	5.7	6.3	5.2
3	4.6	4.8	4.5
4	5.7	5.7	5.3
5	5.4	6.1	6.1
6	6.8	5.4	5.8

Table 6. HGI trial pre/during/post round blood glucose (mmol/L)

Subject	**Pre HGI**	**During HGI**	**Post HGI**
1	6.9	5.7	5.2
2	7.5	5.7	5.2
3	4.4	5.9	4.3
4	4.7	5.3	5.2
5	5.2	5.2	5.9
6	6.8	5.4	5.8

Table 7. LGI trial performance statistics

Subject	SSC score LGI	FIR (/14) LGI	GIR (/18) LGI	Putts LGI
1	77	3	5	30
2	75	8	7	0*
3	73	7	6	27
4	69	4	10	33
5	71	4	2	29
6	69	14	14	34

*incorrectly recorded

Table 8. HGI trial performance statistics

Subject	SSC score HGI	FIR (/14) HGI	GIR (/18) HGI	Putts HGI
1	74	7	4	30
2	75	8	12	39
3	70	5	7	27
4	75	5	8	30
5	0*	7	2	0**
6	72	11	9	32

*No score returned **not recorded